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MATHEMATICS EDUCATION: MODIFYING BY USING INFORMATION AND COMMUNICATION TECHNOLOGIES

O. Grytsiuk
Kremenchuk Mykhailo Ostrohradskyi National University
vul. Pershotravneva, 20, Kremenchuk, 39600. Ukraine. E-mail: mybox_ua@mail.ru

Purpose. The paper deals with the research of the ways of implementing of information and communication technologies in teaching mathematics of engineering students. **Methodology.** The research includes analysis of engineer training with broad implementing of information and communication technologies in mathematical methods system to provide forming of mathematical competences, which is expressed in ability for use of the mathematical modeling method in computer realization for solution of engineer problems in professional activity. **Results.** The paper discusses of using ICT in the mathematics training of engineering students with the aim of improving the training quality. Special attention is given to the solution of engineering problems by methods of mathematical modeling using information and communication technologies. **Originality.** It is proposed in this research the innovative engineer training didactic model, using the Competence-Based Teacher Education principles and integrating elements of computer-based mathematics into traditional teaching methods. **Practical value.** Mathematical modeling of engineering problems contributes to the system of professional knowledge formation and makes unity of learning process with logical structure. **Conclusions.** The mathematics courses provide abilities for the development of students' technical and logical thinking, ability to solve complex engineering problems, both in the learning process, and in future professional activity. References 15, figure 1.

Key words: mathematics education, teaching mathematics, information and communication technologies, engineer training, computer-based mathematics.

МАТЕМАТИЧЕСКОЕ ОБРАЗОВАНИЕ: МОДИФИКАЦИЯ ПУТЕМ ИСПОЛЬЗОВАНИЯ ИНФОРМАЦИОННЫХ И КОММУНИКАЦИОННЫХ ТЕХНОЛОГИЙ

Е. С. Грицюк
Кременчугский национальный университет имени Михаила Остроградского
ул. Первомайская, 20, г. Кременчуг, 39600, Украина. E-mail: mybox_ua@mail.ru

Изучено пути внедрения информационных и коммуникационных технологий в математической подготовке студентов инженерных специальностей. Исследование включает анализ инженерной подготовки с широким внедрением информационных и коммуникационных технологий в систему математических методов с целью обеспечения формирования математической компетентности, выражающейся в способности к использованию метода математического моделирования в компьютерной реализации для решения инженерных задач в профессиональной деятельности. Среди основных методологических подходов в первую очередь был использован системный, позволяющий рассмотреть проблему во взаимосвязи, развитии и движении всех ее элементов; выявить интегративные системные свойства и качества. Предпринята попытка краткого анализа инженерной подготовки с широким внедрением информационных и коммуникационных технологий в систему математических методов с целью обеспечения формирования математической компетентности, которая выражается в способности к использованию метода математического моделирования в компьютерной реализации для решения инженерных задач в профессиональной деятельности. Особое внимание уделяется решению инженерных задач методами математического моделирования с использованием информационных и коммуникационных технологий, а также исследованию путей внедрения информационных и коммуникационных технологий в математической подготовке студентов инженерных специальностей. Материалы статьи могут быть использованы для профессиональной подготовки в высших учебных заведениях (университетах) во время изучения компьютерной математики.

Ключевые слова: математическое образование, математическая подготовка, информационные и коммуникационные технологии, инженерная подготовка, компьютерная математика.

PROBLEM STATEMENT. The rapid development and use of information and communication technologies (ICT) has become one of most important factors of engineering education modifying. An innovation in engineering training requires implementing of ICT in the teaching mathematics process, involving complex information systems and software, e.g. MathCAD, Computer-Aided Design system (CAD) for solving mathematical problems with a computer algebra system using the unique visual format. The engineer must know the latest achievements in science and technology, advanced technology, navigate freely in the modern information systems and software tools based on scientific and methodological apparatus of computer-based mathematics and mathematical modeling method (Building Information Modeling (BIM), Computer-aided engineering (CAE), CAD, CAM and GIS systems etc.). Therefore, mathematics education process can't be imagined without using ICT now. The use of computer during the training, computerization of mathematical operations, simultaneously with traditional forms opens up new possibilities in the training of engineering staff.

This research aims to comprehensive investigation of mathematics training of engineering students in aspect of the implementing of ICT. It is important to focus on the following research tasks:

– to define the leading pedagogical innovations in mathematics training;

– to concretize their relevance in aspect of contemporary transformations of university education;

– to determine the conditions of pedagogical innovations implementation in teaching mathematics of engineering students;

– to investigate ways of implementing ICT in the mathematics engineer education process at professional and technician level.

The rapid growth in the use of ICT in recent years was reflected on the teaching mathematics process in universities. Now, Ukrainian higher education is in a difficult and complicated process of radical restructuring through the integrating of computer-based mathematics, use of multimedia complexes, laboratory exercises on personal computers (PC) into formal lectures and practical classes. As learning mathematics has a certain specificity, which is, first, in the high level of abstractness of educational material and the need for much effort to master them, this subject requires attention in the aspect of didactics and methodology of teaching.

According to P. Kent and R. Noss [1], the level of mathematical skills needed at entry to engineering courses needs resolving. It is clearly connected to outputs expected from schools, but that is not the only issue. There is also the need to resolve how changes could be made to the teaching of the engineering sciences, in particular to allow students with different mathematical skills at entry to flourish. Universities, understandably, that are given the resources, might hope the problem will go away.

In recent years, for various reasons, in Ukraine there has been a steady decrease of prestige and popularity of engineering, so students who come to higher education institutions, as a rule, have low motivation and poor mathematical knowledge. As a result, there is a paradox when universities are not able to meet the needs of modern high-tech industry for highly qualified engineers capable of innovation. This calls for a radical revision of the principles of teaching mathematical courses, significant changes of the educational process, development of pedagogical activities complex to implement the objectives of improving the quality of engineer education and teaching mathematics in particular.

The use of latest information educational technologies and implementation of their possibilities in mathematics at the technical universities are very important [2–4]. Therefore, mathematics education is the theoretical basis for the professional competencies formation of engineering students. In recent time the trend of extending range of problems to be solved by mathematical methods is observed. Mathematics finds broad use in Computer-Aided Design (CAD) and Management Information Systems (MIS). Information logical modeling, mathematical modeling, computer simulation, computational experiment, control software, pattern recognition, classification and identification of images, expert evaluation, testing and others are related with mathematical methodology.

This means that these two factors – the need for modifying mathematics training and strengthening the relation of mathematics with computer-based engineering – determine the relevance of the ICT implementation in teaching and learning process.

EXPERIMENTAL PART AMD RESULTS OBTAINED. Competence-based teaching education (CBTE) approach is the most important in the aspect of professional preference training. It involves the readiness and ability of a student to solve professional and social problems. In pedagogy the development of competence-based approach was started with the works by S. Kemmis [5], R. B. Howsam and W. R. Houston [6]. According to R. B. Howsam and W. R. Houston [6, p. 3], authors of the prime reference book on CBTE, the word *competency* has been chosen to indicate an emphasis on the "ability to do", in contrast to the more traditional emphasis on the "ability to demonstrate knowledge".

Preparing teachers involves preparing them for a wide variety of roles and developing related competencies. However, the extent of emphasis required to be placed on each of these roles or competencies during a teacher training program may vary according to its culture and the context [7, p. 383].

G. Donelli and F. MacSweeney [2] pay attention to the fact that the spread of modern means and methods of learning, new and innovative technologies in engineer education significantly enriches and enhances learning. The trends of the diversity and complexity of E-learning systems are observed. It provides more opportunities for integration, concentration and choice of resources and systems. Nevertheless, the quality of training materials for E-learning remains a problematic issue. The development of the student adaptive model, which would take into account personal characteristics, such as level of knowledge, personal data, current learning outcomes, and the development of technologies for tracking his educational trajectory is complicated mathematical and methodological problem.

When students use technology as a tool or as support for communicating with others, they are in an active role, rather than the passive role of recipient of information transmitted by a teacher, textbook, or broadcast. The student actively makes choices about how to generate, obtain, manipulate, or display information. Technology prompts students to actively think about information, making choices, and executing skills in a manner that is not typical in teacher-led lessons. Each student can be involved in independent or small-group work with the technology. Moreover, when technology is used as a tool to support students in performing authentic tasks, the students are in the position of defining their goals, making design decisions, and evaluating their progress [2].

According to I. Markut [8], the positive feature of problem-based learning is that students possess the skills, verbalization, because they must formulate the conditions, and then to prove that the solution to the problem is correct and effective.

M. Matthews [3] proposes to base mathematics training on the principles of constructivism. The researcher argues for a more use of constructivism as one of the main theoretical fields of modern science and mathematics education, which significantly affects its conceptual principles. This field became the foundation for a broad reform of the education program. Although

it began as a learning theory, gradually constructivism spread to teaching theory, education theory, the theory of the sources of ideas and the theory of individual and scientific knowledge. Constructivism has become an educational version of the great unifying theories. As such it has significantly contributed to mathematical science and education, because it changed the teaching function from providing information to the provision of skills to seek information for themselves, and it transformed the process of mastering new material, emphasized the importance of understanding as the primary goal of teaching, increased the role of activity in the classroom, and also became the source of other progressive transformations.

Modifying of modern technical education may be possible by implementing of new ICT in the educational process. Creating conditions for the functioning of the information-educational environment is gaining importance in the processes of development and self-development ability and intellectual capacity of the student. It means didactic computer environment, which is formed and developed in conditions of informatisation of education. It is necessary in technical universities along with the learning of theoretical courses of professional preference to give more time for ICT, computer-based mathematics, which are the basic components of professional activity of engineering students.

In the process of learning the basic mathematics courses today it is accumulated sufficient experience and significant factual material of methodical systems in learning such courses. However, these systems do not correspond sufficiently to new educational paradigm, in particular, in the use of ICT for intensification of the learning process, development of creative thinking of students, building skills to work in a computer environment.

The use of information systems and software tools requires substantial revision of the learning content. Also, very relevant is the solution of the efficient combination of ICT with others, including traditional forms and training methods. The complex of these measures makes it possible to realize high-quality students training according to new standards of education and social requirements. According to A. Duru, M. Peker and O. Birgin [9], teacher education programs should provide teachers with supportive educational experiences in the successful use of computers in learning and teaching mathematics, and computer-based instruction should be made compulsory for students at faculties of education. Teachers must be encouraged to use computers in their future classroom.

Nevertheless, instrumented techniques are a key in the teacher practices linked to integration. Instrumented techniques are also the visible part of instrumental geneses. During their elaboration, the teacher will have to guide the student in his (her) construction of technological and mathematical knowledge. The teacher is not prepared for this new role [10].

In all researches concerning the implementing of ICT in teaching mathematics, there is a need-based approach to the use of ICT in the learning process, accounting of mathematics specificity as an academic course, its terminology and conceptual apparatus, the specific research methods and patterns, and implementing of modern methods of mathematical processing of information.

Research conducted by T. Poyasok [11] analyses the didactic potential of information technology at each stage of the learning process. According to the researcher, information technology training is an important factor in improving the quality of training. They can be used at all stages of the educational process, but the effectiveness of their application depends on the specific objectives of the learning subjects or professional training generally. The use of ICT in training requires appropriate software, fluent educators and students of the technique, obtaining a certain part of the working time for the development of information content of courses.

Among the positive effects of the implementing of ICT tools and software in mathematics education of engineering students it is worth to distinguish the main positive factors on mathematics training:

– ability to create additional motivation for learning mathematics on the basis of the aspirations of students to cognitive activity;

– accounting of individual psychological and pedagogical characteristics of students;

– forming through ICT special conditions for stimulating of mathematics training at all stages of training due to activation of interdisciplinary connections, implementing the elements of problem-based learning (PBL), etc.

In research conducted by British Educational Communications and Technology Agency [12], factors for effective use of ICT in mathematics are:

– the most appropriate hardware, software and support is available;

– students are equipped with ICT skills which are adequate to achieve the objectives set for them;

– students are encouraged to take advantage of the automation of tasks and instant feedback by ICT, making use of conjecture and applying trial and error methods in their work;

– teachers are aware of the range of software available, and select programs to support particular learning skills;

– on and off-computer time is balanced in accordance with learning needs.

According to A. Jones [13], factors inhibiting ICT use in teaching mathematics are:

– lack of confidence among teachers during integration;

– lack of access to resources;

– lack of time for the integration;

– lack of effective training;

– facing technical problems while the software is in use;

– lack of personal access during lesson preparation.

Active implementing of ICT tools and software in educational process results in adjustment of the training content, the new principles of its modeling, causes substantially revise the organisation of educational process, in particular referring to the redistribution of volumes of lectures and practice in favor of the latter and practical training on the PC. Thus, the engineering student should

be highly skilled in solving specific engineering tasks using mathematical techniques and ICT.

According to unit of competency research conducted by a Joint Initiative of the Australian and State and Territory Governments [14], the elements described the essential outcomes of engineer mathematical competencies and techniques, involves:

– *Determine scope of technical mathematical techniques required for an engineering application:*

– analyse an engineering application for required technical mathematical tasks;

– develop systematic methods for layout and solution checking;

– determine mathematical software required for analytical and graphical solutions and validate software using traditional solutions to simple examples;

– *Apply technical mathematical techniques to engineering application:*

– use appropriate software for analytical and graphical solutions;

– convert between different number systems;

– use appropriate mathematical techniques required for analysis and solution;

– use appropriate data representations to communicate the solution to others;

– report results and document calculations, graphs and analysis.

Without denying the importance and necessity of implementing of ICT in the educational process, it should be borne in mind that the main goal of computer training of specialist is to develop the student's understanding of the possibilities of using information technology in the future professional activity. This understanding should be based on knowledge of the relationships and dependencies between the basic mathematical and natural scientific courses, general technical and special engineering subjects.

Sufficient experience in the use of ICT in the engineering students training has accumulated in Kremenchuk Mykhailo Ostrohradskyi National University (Ukraine). The use of multimedia complexes in teaching lecture material is one way of implementing of ICT in engineering training. The quality of teaching material significantly improves and its informational content increases. Currently Virtual Computer-based Laboratory Systems (CLS) and Computer-based Educational-Methodical Complexes (CEMC) of academic courses are actively implemented. In result efficiency of students' individual learning increases and the methodological support of educational courses is improved.

One of the main tasks of the university is forming and development of information databases and computer classrooms for teaching mathematics. To implement this ICT tools it is necessary to develop innovative didactic model of engineer training toward using ICT. The didactic model of mathematics engineer training provides consistent implementation of ICT at all stages of learning. The didactic model may be defined as the development of training modules, included in the educational process of learning not only mathematics, but also professionally-oriented courses, development of systems, including both with the main learning modules and the elements of computer-based mathematics and ICT.

Formal lecturers should be supplemented by compulsory reading, handouts, elements of small group teaching and formative assessment [15].

Figure 1 shows a simple sequence of modules that are included in the process of teaching and learning mathematics using PC and ICT.

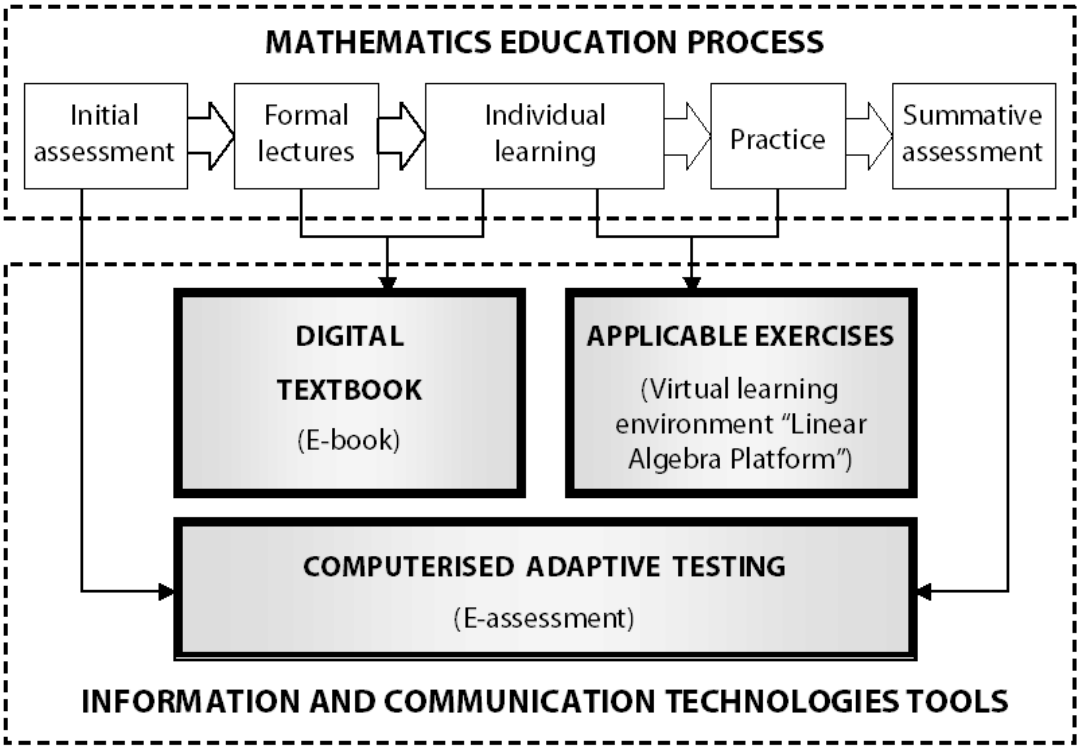

Figure 1 – The sequence of modules in the mathematics education of engineering students using ICT tools

The innovative form of conducting the engineering laboratory exercise during the organisation of mathematics practice is proposed. The teacher' main task during such laboratory exercise is real-time monitoring of students' activities and correction of their work at the same time. This approach allows the best way to reveal the individuality of each student. Testing of mathematical knowledge level occurs immediately after the practical exercises using Virtual Computer-based Laboratory Complex (VCLC), and not only by summative assessment. The educator checks the exercises results, explores the logic of decision, systematizes and generalizes the results of the whole students group. This process is going in terms of real-time and instant results demonstrating on-screen so that the students could immediately correct the learning process. While working with VCLC the student submits to check 3–4 times more engineering mathematics exercises than in the traditional approach. Thus, teacher could not be deprived of the main functions using computer-based systems, but greatly enhance them.

The mathematics education organized in such way allows optimizing and intensifying of the educational process and brings it closer to the future professional activity. Due to the active use of applied problems in the practical part of the course and self-study, prerequisites for the integration of mathematics and engineering courses are formed.

CONCLUSIONS. 1. It is proposed in this research the innovative engineer training didactic model, using the Competence-Based Teacher Education principles (CBTE) and integrating elements of computer-based mathematics into traditional teaching methods. It includes an extensive implementing of ICT in the system of mathematical methods and their applications to ensure the development of mathematical competence, which is expressed in the ability to apply computer-based mathematics methods in the professional activities to solve engineering problems.

2. Modern engineer training program built on the basis of competence approach and the integrative principle provides a broad implementing of ICT in the integrated system of mathematical methods. The principles of concentration and intensification contribute to effective organisation of educational process with ICT tools use. Mathematical modeling of engineering problems contributes to the system of professional knowledge formation and makes unity of learning process with logical structure.

3. The mathematics courses provide abilities for the development of students' technical and logical thinking, ability to solve complex engineering problems, both in the learning process, and in future professional activity. The aspects of modifying of mathematics training of engineering students determine the relevance of an integrated approach to its solution. Naturally, integrity, systematic, unified orientation of all kinds of learning is the main concept of mathematics education of engineering students.

REFERENCES

1. Kent, P., & Noss, R. (2003), Mathematics in the University Education of Engineers, A Report to the Ove Arup Foundation, available at: http://www.lkl.ac.uk/research/REMIT/Kent-Noss-report-Engineering-Maths.pdf (accessed March 12, 2015).

2. Donnelly, R., & McSweeney F. (2009), *Applied E-Learning and E-Teaching in Higher Education: Information science reference*, Hershey, New York, USA.

3. Matthews, M.R. (2000), "Constructivism in Science and Mathematics Education", *National Society for the Study of Education. – 99th Yearbook,* University of Chicago Press, Chicago, USA, pp. 161–192.

4. Subbotin, I. (2008), "An integrated approach in teaching algebra and number theory: best practices", *Didactics of Mathematics: Problems and Investigations,* vol. 30, pp. 50–55.

5. Kemmis, S., & Stake, R.E. (1974), "Operational vs. Judgmental Assessment of Teacher Competence", *Educational Leadership*, vol. 1, pp. 322–323.

6. Howsam, R.B., & Houston, W.R. (1972), *Competency-based teacher education: Progress, problems and prospects*, Science Research Associates, Inc, Chicago, USA.

7. Bawane, J., & Spector, M. (2009), "Prioritization of online instructor roles: implications for competency-based teacher education programs", *Distance Education,* vol. 30, no. 3, pp. 383–397.

8. Marcut, I. (2005), "Critical thinking – applied to the methodology of teaching mathematics", *Educatia Matematica*, vol. 1, no. 1, pp. 57–66.

9. Duru, A., Peker, M. & Birgin, O. (2012), "Investigation of Pre-Service Teachers' Attitudes toward Using the Computer in Teaching and Learning Mathematics", *The New Educational Review,* vol. 27, no. 1, pp. 283–294.

10. Lagrange, J.B. (2009), "Analysing the impact of ICT on mathematics teaching practices", *European Research in Mathematics Education III: Proceedings of the 3^{d} Conference of the European Society for Research in Mathematics Education, CERME 2009, Bellaria, Italia*, available at: http://www.dm.unipi.it/~didattica/CERME3/proceedings/Groups/TG9/TG9_Lagrange_cerme3.pdf (accessed April 23, 2015).

11. Poyasok, T.B. (2009), System of use of information technologies in the vocational training of future economists in higher educational institutions. Thesis for the degree of Doctor of pedagogical sciences: 13.00.04. Kyiv, Ukraine.

12. BECTa (2003), What the research says about using ICT in Maths, BECTa, Coventry, available at: http://archive.teachfind.com/becta/research.becta.org.uk/upload-dir/downloads/page_documents/research/wtrs_maths.pdf (accessed December 7, 2014).

13. Jones, A. (2004), A review of the research literature on barriers to the uptake of ICT by teachers, BECTa, UK, available at: http://dera.ioe.ac.uk/1603/1/ becta_2004_barrierstouptake_litrev.pdf (accessed June 1, 2015).

14. A Joint Initiative of the Australian and State and Territory Governments. Unit of competency details: apply technical mathematics (2012), available at:

http://training.gov.au/Training/Details/MEM23004A (accessed April 27, 2015).

15. Sazhin, S.S. (1998), "Teaching Mathematics to Engineering Students", *International Journal of Engineering Education*, vol. 14, no. 2, pp. 145–152.

МАТЕМАТИЧНА ОСВІТА: МОДИФІКАЦІЯ ШЛЯХОМ ВИКОРИСТАННЯ ІКТ

О. С. Грицюк

Кременчуцький національний університет імені Михайла Остроградського

вул. Першотравнева, 20, м. Кременчук, 39600, Україна. E-mail: mybox_ua@mail.ru

Досліджено шляхи впровадження інформаційних і комунікаційних технологій у математичній підготовці студентів інженерних спеціальностей. Дослідження включає аналіз інженерної підготовки з широким впровадженням ІКТ у систему математичних методів з метою забезпечення формування математичної компетентності, що виражається у здатності до використання методу математичного моделювання у комп'ютерній реалізації для вирішення інженерних задач у професійній діяльності. Розглядається використання ІКТ під час навчання математики студентів інженерних спеціальностей з метою підвищення якості навчання. Особлива увага приділяється вирішенню інженерних задач методами математичного моделювання з використанням ІКТ.

Ключові слова: математична освіта, математична підготовка, інформаційні та комунікативні технології, інженерна підготовка, комп'ютерна математика.

ЛІТЕРАТУРА

1. Kent P. Mathematics in the University Education of Engineers. A Report to the Ove Arup Foundation. – London : London Knowledge Lab, 2003. – Retrieved 25/10/2014, from http://www.lkl.ac.uk/research/REMIT/Kent-Noss-report-Engineering-Maths.pdf.

2. Donnelly R., McSweeney F. Applied E-Learning and E-Teaching in Higher Education : Information science reference. – New York : Hershey, 2009. – 415 p.

3. Matthews M. R. Constructivism in Science and Mathematics Education // National Society for the Study of Education / In D.C. Phillips (ed.). – 99th Yearbook. – Chicago : University of Chicago Press, 2000. – PP. 161– 192.

4. Subbotin I. An integrated approach in teaching algebra and number theory : best practices // Дидактика математики : проблеми і дослідження : Міжн. зб. наук. робіт. – Донецьк : Вид-во ДонНУ, 2008. – Вип. 30. – С. 50–55.

5. Kemmis S., Stake R. Operational vs. Judgmental Assessment of Teacher Competence // Educational Leadership. – 1974. – № 1. – PP. 322–323.

6. Howsam R. B., Houston W. R. Change and Challenge / Competency-based teacher education : Progress, problems and prospects; Howsam R. B., Houston W. R., editors. – Chicago : Science Research Associates, Inc., 1972. – 224 p.

7. Bawane J., Spector M. Prioritization of online instructor roles : implications for competency-based teacher education programs // Distance Education. – 2009. – Vol. 30, № 3. – PP. 383–397.

8. Marcut I. Critical thinking – applied to the methodology of teaching mathematics // Educatia Matematica. – 2005. – Vol. 1, № 1. – PP. 57–66.

9. Duru A., Peker M., Birgin O. Investigation of Pre-Service Teachers' Attitudes toward Using the Computer in Teaching and Learning Mathematics // The New Educational Review. – 2012. – Vol. 27 (1). – PP. 283–294.

10. Lagrange J. B. Analysing the impact of ICT on mathematics teaching practices // European Research in Mathematics Education III: Proceedings of the 3d Conference of the European Society for Research in Mathematics Education (CERME 2009. Bellaria, Italia). – Retrieved 25/10/2014, from http://www.dm.unipi.it/~didattica/CERME3/proceedings/Groups/TG9/ TG9_Lagrange_cerme3.pdf.

11. Поясок Т. Б. Система застосування інформаційних технологій у професійній підготовці майбутніх економістів у вищих навчальних закладах: автореф. дис. … д-ра пед. наук : 13.00.04 "Теорія та методика професійної освіти". – К., 2010. – 44 с.

12. BECTa ICT Research. What the research says about using ICT in Maths. – Coventry : BECTa, 2003. – Retrieved from http://webarchive.nationalarchives.gov.uk/20130401151715/http://www.education.gov.uk/publications/eOrderingDownload/15014MIG2799.pdf.

13. Jones A. A review of the research literature on barriers to the uptake of ICT by teachers. – BECTa, UK, 2004. – Retrieved 30/06/2014, from http://dera.ioe.ac.uk/1603/1/becta_2004_barrierstouptake_litrev.pdf.

14. A Joint Initiative of the Australian and State and Territory Governments. Unit of competency details : apply technical mathematics. – 2012. – Retrieved 30/10/2014, from http://training.gov.au/Training/Details/MEM23004A.

15. Sazhin, S.S. Teaching Mathematics to Engineering Students // International Journal of Engineering Education. – 1998. – Vol. 14, № 2. – PP. 145–152.

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